

Hong Kong's chemical community  
feels impact of 1997 reintegration  
with China Page 21

OCTOBER 22, 1990

A1250-1

CHEMICAL & ENGINEERING

# NEWS

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## News of the Week

■ Nobel Prizes in Chemistry and Physics announced, with chemistry award going to Harvard's Elias J. Corey. **Page 4**

■ Third-quarter chemical earnings reported so far indicate that earnings may be down at firms heavily tied to downstream petrochemical products, but up at others. **Page 5**

■ White House appoints 39-year-old physician/lawyer David A. Kessler as new FDA Commissioner. **Page 5**

■ Japanese researchers demonstrate a novel, three-state chemical method based on an azobenzene derivative that may prove useful for information storage. **Page 6**

## Business

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## Employment Outlook

**C&EN's annual look at the job market compares salaries earned by chemists and chemical engineers with those of other professionals.** **Page 30**

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## Chemical & Engineering News

1155—16th St., N.W., Washington, D.C. 20036

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Published by  
AMERICAN CHEMICAL SOCIETY  
(202) 872-4600; TDD (202) 872-8733  
John K. Crum, Executive Director

Robert H. Marks, Director, Publications Division  
PUBLISHING BOARD: Jeanne M. Shreeve (Chairman); Board of Directors Chairman: Joseph A. Dixon; President: Paul G. Gassman; Richard L. Deming; William P. Jencks; Gary J. Long, and Louis D. Quin

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Subscription Rates 1990. Printed editions: nonmembers U.S. 1 yr. \$60, 2 yr. \$108, outside U.S. 1 yr. \$93, 2 yr. \$174. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3-10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current \$9.00. Rates for back issues and volumes are available from Microfilms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

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## LETTERS

### Iodine-doped polymers

In the debate on the conduction mode in iodine-doped nonconjugated polymers (C&EN, May 7, page 53; June 4, page 2), all participants have overlooked one piece of data that, to us, seems highly relevant: In 1980, I. Rubinstein and E. Gileadi (*J. Electroanal. Chem.*, **108**, 191) proposed a "super-ionic" relay conduction mode for the system iodine doped with 1M potassium iodide. The maximum conductivity was determined to be  $10^{-2}$  siemens per cm, the same order of magnitude as was determined for "conducting rubber" and all other iodine/polydiene complexes. With iodonium complexes (Bruce Hudson), iodonium complexes (Gary Wnek), iodine ions in systems with up to 60 to 70% (Mrinal K. Thakur), iodine can readily do the job.

A. H. Alberts

E. W. Meyer

Eindhoven Technical University  
The Netherlands

### Opera fan of Risè Stevens

As an opera lover and fan of the Met, I must take exception to John H. Nair's deprecation of Risè Stevens, calling her "a minor opera singer" (C&EN, Sept. 24, page 3). Her definitive portrayal of "Carmen" alone earned her international acclaim as one of the great operatic artists of her time.

Hans Wagner

Wilmington, Del.

### Kekulé's dreams

In Royston M. Roberts' review of Alexander Kohn's book, "Fortune or Failure: Missed Opportunities and Chance Discoveries in Science" (C&EN, July 23, page 61), Roberts disagreed with Kohn, who considered Kekulé's claim to have discovered the structure of benzene in a dream a "myth which has recently been laid to rest." Roberts backs up his difference of opinion by calling attention to "considerable current interest, as indicated by recent controversial publications and a [Kekulé] symposium presented by the Division of History of Chemistry at the Boston national meeting of the American Chemical Society last April."

I was the organizer of the Boston two-day Kekulé symposium. Indeed there was a lot of interest. We had speakers from the U.S., Belgium, Germany, the

Soviet Union, and the U.K. Besides participation by chemists, there were presentations by historians of chemistry and of science, psychology, and psychiatry. When the papers are published in 1991 in book form by Springer-Verlag, I believe that your readers will side with Kohn's opinion. I believe that the chapter by the psychiatrist Albert Rothenberg, the director of research at Austen Riggs Center Inc., in Stockbridge, Mass., will be the last word that will support the revisionistic appraisals of the other investigators who considered Kekulé's dreams to be fictional.

John H. Wotiz

Professor Emeritus  
Southern Illinois University

Royston M. Roberts referred to the American Chemical Society symposium in Boston regarding August Kekulé's discovery of the structure of benzene. At that symposium, I presented three commissioned expert English translations of Kekulé's original German description of the mental events leading to the discovery. All of these translators independently indicated that the word Kekulé used to describe his mental state, "Halbschlaf," did not refer to actual sleeping, the only mental state in which dreaming can occur. Also, other aspects of his own description contain clear references to his having visualized mental images in a waking state of mind.

Much of the misconception about the matter of dreaming has arisen from a faulty English translation done in 1898 by Francis R. Japp. In context, Kekulé's use of the verb to dream (*träumen*) seems clearly to have been intended as a figurative term in a manner similar to Martin Luther King's famous phrase, "I have a dream," meaning imagining or being inspired. Actual dreaming, it should be emphasized, is not the same psychological state as imaginative or in-

### Correction

• Oct. 1, page 7: The U.S. Patent & Trademark Office has said that an interference between claims to single-chain antigen-binding proteins in Creative BioMolecules' pending patent application and a patent held by Genex Corp., Gaithersburg, Md., has not been declared. In early September, Creative BioMolecules filed a request for an interference, which, according to the company, is still pending.

# EPA's Emissions Inventory Shows Some Pollution Reduction

**Tally of 1988 reports from industry reveals 11% drop in emissions, chemical transfers from 1987 with chemical firms making greatest strides**

David J. Hanson, C&EN Washington

An Environmental Protection Agency analysis of the 1988 Toxic Release Inventory finds that U.S. industry is beginning to reduce emissions of toxic chemicals, but it still has a long way to go. Chemical companies, which release the greatest amounts of toxic chemicals, are also the facilities making the greatest reductions in emissions and waste reduction.

This second national report on the toxic inventory says that companies' emissions and chemical transfers are down 11% from totals reported the previous year. These reductions come from pollution prevention and a lesser amount of hazardous chemicals being sent to municipal water treatment works or shipped to other treatment/disposal facilities.

The raw numbers were made available last April. U.S. companies reported emitting 360 million lb of toxic chemicals into rivers, lakes, and other bodies of water; 2.43 billion lb into the air; 560 million lb to landfills; and 1.22 billion lb into underground wells.

According to EPA, Texas and Louisiana accounted for 24% of all releases and transfers of chemicals on the Toxic Release Inventory. Just three chemical companies—Du Pont, Monsanto, and American Cyanamid—reported releasing 710 million lb of chemicals into the environment, 15% of the national total. The chemical industry also had the greatest amount of pollution reduc-

tion, 11.6 million lb, of any single industry group.

The toxic inventory is part of the Emergency Planning & Community Right-To-Know Act, passed in 1986 as part of the Superfund reauthorization. The law requires all manufacturing companies that use certain levels of chemicals to detail how much they emit into the environment. The list of toxic chemicals Congress wrote into the law is a combination of lists developed by the states of Maryland and New Jersey for their own purposes.

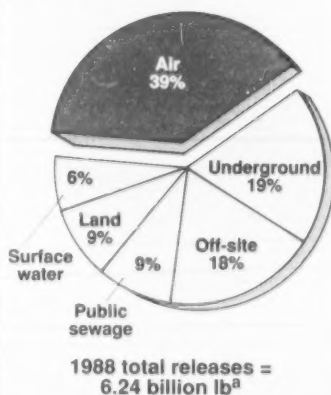
The original list covered more than 320 chemicals and chemical categories. About 120 of those substances are considered carcinogens for the purpose of reporting. One chemical, Freon 113, is on the list solely because of its purported danger to Earth's stratospheric ozone. Some of the original listed chemicals, such as sodium sulfate, turned out to be not very toxic and were taken off the list, while others have been added.

In 1989 EPA received more than 70,000 forms from 19,762 facilities reporting their 1988 emissions. This is about 100 more facilities than reported 1987 emissions and an increase of about 4400 forms. Much of the difference stems from a lower reporting threshold used for 1988 reporting. In 1987 facilities had to manufacture at least 75,000 lb of a chemical before reporting was required. For 1988 the threshold was reduced to 50,000 lb, and next year it will be 25,000 lb. Despite the large number of facilities that did file forms, EPA estimates there are nearly 10,000 more companies that should be filing but are not.

Although these chemicals are labeled toxic for the purpose of the inventory, EPA cautions several times in its report that the releases reported are not an indicator of any human health or environmental problems. According to EPA's David Sarokin, project manager for the Toxic Release Inventory report, this is the first time EPA has made any comments about possible health effects. "The question of what is and what is not a toxic chemical is very difficult to answer. What we did in the report was to present the status quo—if a chemical was labeled as highly toxic on the inventory, we just carried that on over into the report."

Following the release of the preliminary data, a number of activist environmental groups released compilations of numbers designed to inform local residents of the large numbers of "toxics" in their communities. The National Wildlife Federation, for example, published a document called "Phantom Reductions" decrying the fact that most of the reported reductions from large companies were the result of changes in reporting requirements and new estimation methods.

**Air emissions are largest source of toxics**



<sup>a</sup> Emissions of substances on Toxic Release Inventory. Source: Environmental Protection Agency

## EPA continually revises its toxics inventory

The Toxic Release Inventory is not a static list of chemicals. The Environmental Protection Agency has the ability and obligation to revise the list to keep it accurate and up to date. Since the law requiring compilation of the inventory was enacted in 1986, a number of chemicals have been removed and added.

Between the 1987 and 1988 reporting dates, EPA deleted four chemicals from the list. Three of the chemicals—C.I. Acid Blue No. 9 (diammonium salt), C.I. Acid Blue No. 9 (disodium salt), and melamine crystal—were of minor importance. But deletion of the other one—sodium sulfate—had a major impact, because sodium sulfate by itself, accounted for 55% of the total releases and transfers reported in 1987. Data on

it were dropped from the 1987–88 comparisons.

Deleted from the inventory data for 1989 will be sodium hydroxide and non-fibrous forms of aluminum hydroxide. These also have large-volume releases and will cut the total release amount of chemical "contaminants" considerably.

But chemicals are being added, too. For the 1990 reporting period, EPA will add nine compounds: allyl alcohol; creosote; 2,3-dichloropropene; *m*-, *o*-, and *p*-dinitrobenzene; dinitrotoluene; isosafrole; and toluene diisocyanate. Nine chemicals are proposed for deletion next year as well. The largest volume of these are phthalic anhydride, terephthalic acid, and butylbenzyl phthalate. These contribute about 16 million lb to the annual inventory.

Sarokin admits that this is true, but says it is still too early to be extrapolating any kinds of trends from the data. When companies compiled their first reports for 1987, many, if not most, were confused about just what had to be reported and were unsure of how to estimate their emissions. EPA reported that almost all the early forms submitted were done incorrectly and had to be amended. Adjustments in the second year were expected, Sarokin says, although it is unusual that almost all of them were down. Overall, two thirds of the reductions in emissions are attributed to changes in reporting and revised estimates and one third to actual pollution abatement.

The 3838 chemical facilities (as defined by the standard industrial classification code 28) that filed toxic release forms for 1988 were only 19% of all facilities emitting toxic chemicals, but they accounted for 47% of total chemical releases and transfers. Running a distant second in terms of toxic releases, with 14% of the total, were primary metals (SIC 33). The chemical industry reported an average of four chemicals released per facility and had the greatest number of chemicals reported by one plant, 86 separate chemicals, by Dow Chemical's plant in Freeport, Tex. The petroleum refining indus-

try (SIC 29) averaged the most forms per facility with eight.

Of the 120 chemicals on the toxic list labeled carcinogens, the chemical industry released or transferred three times as many pounds of the top 25 listed carcinogens as any other industry, although carcinogenic releases accounted for only 6% of the chemical industry total. Some of these carcinogenic compounds, such as hexachlorobenzene, are used and released solely by chemical plants. Chemical facilities also account for over 75% of the releases of many other carcinogenic compounds such as 1,3-butadiene and acetonitrile.

The toxic release inventory does not cover all sources of the listed chemicals, because, as EPA points out, many emitters either fall below the reporting thresholds, have less than 10 employees, or are in non-manufacturing industries. The question remains, of course, how much of any chemical's releases are caught by the Toxic Release Inventory?

EPA says it depends. Releases of some chemicals, such as acrylonitrile, are totally captured. Releases of others which are used more widely are not. Benzene and toluene, for example, are found in high concentrations in gasoline, but since tailpipe emissions are not included in the toxic release reporting, these releases aren't counted. EPA is looking

into ways it might expand the inventory reporting to include more nonmanufacturing facilities.

Federal facilities are not required to report toxic release data either, although private contractors running federal facilities are, so the majority of federal releases aren't counted. An EPA survey of federal departments and agencies shows that, with few exceptions, they have made little effort to comply with toxic release reporting voluntarily. The Department of Energy is one exception. Defense Department agencies, on the other hand, are not complying with reporting rules.

Although the agency admits it's too early to see trends, it did make an effort to compare the 1987 and 1988 data. Using what it calls matched data sets, EPA looked at releases of individual chemicals at individual facilities that reported for both years. What EPA found was that many of the decreases and some increases in the total could be traced to large changes at individual plants. All the reported decreases in arsenic releases, for example, were accounted for by one change made at the Kerr-McGee Chemical plant in Trona, Calif.

Waste minimization is a major goal of EPA and the Toxic Release Inventory has a voluntary reporting form to record minimization results. The agency reports that only 10% of the reporting facilities filed minimization forms, not enough to provide any reliable data on national waste minimization efforts or on what methods are being most commonly used. Most of the reductions that were reported were achieved by equipment changes, on-site recycling, and housekeeping improvements. Two methods that are often touted as the best means for reducing toxic pollution—reformulation of processes and substitution of less toxic raw materials—were the least used and caused the least minimization.

Copies of EPA's 400-plus-page report, titled "Toxics in the Community: National & Local Perspectives," are available from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (order number 055-000-00363-7), for \$21 each. □

# 1991 Employment Outlook

Rebecca L. Rawls, C&EN Washington



lowing several years of short supply for these chemical professionals. **Page 39**

## Career Planning

Useful information from the American Chemical Society and other organizations for individuals planning careers in chemistry or chemical engineering includes lists of services, sources of career information, and organizations that can supply guidance about chemical careers. **Page 41**

## Comparing Chemists' Pay with That of Other Professionals

Just how well are chemists paid, compared with other professionals? Judging from letters to C&EN and conversations at chemical gatherings, the subject seems to be much on the minds of chemists these days. Opinions seem to fall broadly into three camps: One, chemistry as a profession doesn't pay as well as other fields that a young person considering chemistry as a career might choose as alternatives. This pay disadvantage is an important reason why so few students choose chemistry as a career. Two, chemistry doesn't pay as well as other fields, but certain people will always find it so rewarding in other ways that they will choose it as their career. And three, chemists have an exaggerated notion of how much typical practitioners of other professions earn. In reality, chemists' pay is comparable to that of equally qualified people in other fields.

In an effort to bring some useful information to the discussion, here are some comparisons of the salaries of chemists with those of people in fields that might seem alternative career choices to young people considering chemistry.

Physicians are often cited as being better paid, by and large, than chemists, and they probably are. According to an American Medical Association survey, the average net income for physicians in the U.S. in 1988 was \$144,700, nearly three times the \$50,000 median salary for Ph.D. chemists that year, as measured in the American Chemical Society's annual survey. (1988 is the most recent year for which AMA has data on physicians' incomes.)

Such an overall comparison, however, may be somewhat deceptive. Physicians in the survey had three or four years of college, four years of medical school, and then one to six

### Some words of caution about the comparisons used in this report

The best way to compare salaries of different professions accurately is to survey a large and appropriately selected sample of people from each field at the same time, making sure to design the survey so that confounding factors, such as amount of education, work experience, age, sex, and type of employer can be taken into account in analyzing the results. No such study exists comparing chemists with the whole range of other professions discussed in this article. By and large, this article compares data from different surveys conducted by different organizations at different times and for different purposes. At best, it can give only a preliminary approximation of the relative salaries of chemists and other professionals.

One example may serve to show just how rough these approximations can be. A survey by the Bureau of Labor Statistics in March 1990 gives an average annual salary of \$46,561 for all chemists working in goods-producing industries. An ACS survey, conducted

the same month, found the average salary for all chemists in industry to be \$55,583, which is nearly 20% higher. Among other differences, the ACS survey is of its members employed in industry, and ACS members are somewhat more likely than industrially employed chemists as a whole to have Ph.D.s. That may be one reason why the ACS survey finds higher salaries. Also, ACS includes member chemists in all industry and the BLS survey is specific to goods-producing industries. Most, but not all, of the jobs for chemists in industry are in the goods-producing sector, so the two surveys examined different populations.

Some drawbacks of the comparisons in this article deserve special mention. Usually different surveys were not carried out at the same time. The comparisons made here are always from surveys conducted in the same calendar year, but salaries can change a lot in the course of a year. The median salary of office-based physicians, for example, rose 12.5% from 1988 to

1989 according to the survey conducted by *Medical Economics*.

Some of the comparisons are of median salaries, some of mean salaries. The median is the salary at which half of the sample is paid more and half less. The mean is the mathematically derived average of the salaries in the sample. A few very high salaries can shift the mean significantly but will usually not affect the median. Thus, medians are a better measure of the typical salary of a group, and whenever medians are available, that's the comparison used here. But when the median isn't available, an average can still tell something. And for large, relatively homogeneous groups, averages and medians will be almost the same. The federal government, for example, employs large numbers of professionals at a limited number of discrete salary levels and has no extreme deviations in salary. Thus, for federal employees, average salaries provide a better measure of typical salaries than they would for all physicians, for example, or all lawyers.

additional years of residence training, depending on their area of specialty. Most Ph.D. chemists don't have that much post-high school professional training—nine years is more typical. Among physicians, the specialty that most closely matches that amount of training is the general or family practitioner. For this specialty, 1988 income averaged \$94,600, still almost twice the typical salary of Ph.D. chemists.

Physicians also differ from chemists in another important factor; most of them are self-employed. Thus they carry business risks and expenses that most chemists don't. According to a survey by the magazine *Medical Economics*, the net income of typical office-based physicians in 1989 was only 53% of the gross receipts from their practices. The rest went for professional expenses. And what's left isn't really comparable to an employee's salary because these physicians also have to pay expenses such as retirement and insurance, items employers ordinarily provide in addition to salary.

In 1988, the AMA survey found

self-employed physicians had an average annual before-tax income of \$160,000; those who were employees averaged \$113,000 in income that year. Physicians who were employees and in general practice averaged \$81,600 in 1988. That's still more than most chemists were earning. The highest paid 10% of Ph.D. chemists that year made \$80,000 or more. About one quarter of Ph.D. chemists with 30 or more years of experience made that much.

According to the *Medical Economics* survey, office-based physicians had a median income of \$132,550 in 1989, up 12.5% from the 1988 median of \$117,780. In 1989 the median income of the highest paid Ph.D. chemists—those working in industry—was \$58,000, or 44% of the physicians' median. More than 90% of office-based physicians earned more than \$58,000 in 1989. The median income for those in general practice was \$86,860, or half again as much as Ph.D. chemists working in industry earned. In the highest earning specialty, cardiovascular surgery, office-based physicians had a median

income of \$296,300, more than four times the \$69,500 that was the average income of Ph.D. chemists that year in their highest earning "specialty"—the petroleum industry.

The 1988 median of \$117,780 found in the *Medical Economics* survey is considerably different from the \$160,000 average salary for the same year found by the AMA, and it points out the difficulty of comparing data from different surveys. Among other differences, the AMA number is average income and the *Medical Economics* figure is median income.

Lawyers are another group renowned for their high incomes, leading some chemists to assume that the typical lawyer probably earns much more than the typical chemist. But here that conclusion may not be so well founded.

The American Bar Association does not survey its members regarding their income, nor could C&EN identify any other organization that surveys the income of the whole spectrum of lawyers. Nevertheless, some helpful statistics are available.

According to a survey of recent law school graduates conducted by the National Association for Law Placement, the median starting salary for lawyers in 1988 was \$35,000; ACS's annual starting salary survey found the median starting salary for Ph.D. chemists that year to be \$40,550, or 16% more than beginning lawyers.

According to a survey by the young lawyer's division of the American Bar Association, the 1990 median income of lawyers who are up to 35 years of age or no more than three years out of law school is \$65,000. ACS doesn't compile data on a strictly comparable group of Ph.D. chemists; perhaps the closest equivalent would be those working in industry five to 14 years after receiving their bachelor's degrees (which would make them about 27 to 36 years old). The 1990 median salary for this group is between \$47,000 and \$50,000.

Lawyers, like physicians, are much more likely than chemists to offer their services directly to the public. In the case of lawyers, this means that many are either self-employed or members of law firms. However, some lawyers do work for corporations that pay them salaries,

### Ph.D. scientists earn less than most engineers

|                                  |                 |
|----------------------------------|-----------------|
| <b>ALL SCIENTISTS</b>            | <b>\$47,800</b> |
| Chemists                         | 50,500          |
| Physicists and astronomers       | 53,400          |
| Mathematicians                   | 46,600          |
| Computer/Information specialists | 54,400          |
| Earth scientists                 | 50,800          |
| Oceanographers                   | 44,300          |
| Atmospheric scientists           | 50,000          |
| Biological scientists            | 44,500          |
| Agricultural scientists          | 44,300          |
| Psychologists                    | 44,300          |
| Economists                       | 50,800          |
| Sociologists and anthropologists | 41,700          |
| <b>ALL ENGINEERS</b>             | <b>\$58,100</b> |
| Chemical                         | 58,900          |
| Civil                            | 53,300          |
| Electrical                       | 60,500          |
| Mechanical                       | 55,700          |
| Nuclear                          | 58,900          |

Note: Median annual salaries for doctoral scientists and engineers in 1987. Source: National Science Foundation

### Engineers, physical scientists among highest paid faculty

| Discipline                 | Average salary, 1989 | % change from 1988 | Average salary, 1989    | % change from 1988 |
|----------------------------|----------------------|--------------------|-------------------------|--------------------|
|                            | Full professor       |                    | New assistant professor |                    |
| Law                        | \$78,875             | 5.8%               | \$43,434                | 1.7%               |
| Computer information       | 67,026               | 5.8                | 40,672                  | 2.3                |
| Business                   | 66,492               | 6.3                | 48,023                  | 8.4                |
| Engineering                | 65,342               | 5.6                | 41,845                  | 5.0                |
| Physical sciences          | 59,122               | 5.7                | 34,003                  | 8.3                |
| Interdisciplinary sciences | 57,562               | 6.4                | 27,579                  | 3.3                |
| Mathematics                | 57,237               | 5.3                | 32,858                  | 4.5                |
| Social sciences            | 56,637               | 6.2                | 30,546                  | 7.9                |
| Psychology                 | 56,599               | 6.4                | 31,492                  | 9.8                |
| Library                    | 56,541               | 6.0                | 32,056                  | 6.0                |
| Area studies               | 55,799               | 4.1                | 29,304                  | 7.0                |
| Public affairs             | 55,582               | 5.4                | 31,204                  | 0.6                |
| Biology                    | 53,997               | 6.8                | 31,994                  | 10.4               |
| Architecture               | 53,337               | 4.7                | 32,013                  | 7.7                |
| Letters                    | 53,083               | 6.3                | 27,596                  | 7.1                |
| Foreign languages          | 52,613               | 6.5                | 26,832                  | 4.7                |
| Communications             | 52,117               | 5.3                | 30,887                  | 4.6                |
| Agricultural sciences      | 51,034               | 5.5                | 32,246                  | 7.3                |
| Education                  | 50,677               | 6.5                | 29,339                  | 5.6                |
| Home economics             | 50,420               | 3.2                | 31,139                  | 5.3                |
| Fine arts                  | 46,819               | 5.7                | 26,667                  | 8.0                |
| ALL MAJOR FIELDS           | \$57,997             | 5.7%               | \$34,164                | 5.4%               |

Note: Data are for 1989-90 academic year for faculty at institutions belonging to the National Association of State Institutions & Land-Grant Colleges. Source: American Association of University Professors

and this is the segment of the legal profession that is probably most fairly compared with chemists who are similarly employed. The Bureau of Labor Statistics, in its annual survey of the pay of professional, administrative, technical, and clerical workers, collects data on both attorneys and chemists working in industry. This survey examines workers in goods-producing industries one year and in service-producing industries the next.

The March 1990 survey of goods-producing industries found an average salary for chemists of \$46,561. BLS divided the jobs of chemists into seven levels based on education requirements, duties of the job, and supervisory responsibilities. Disregarding the levels generally held by people with less than a Ph.D. raises the average salary for chemists in the survey to \$57,763. Attorneys' salaries, which were divided into six levels, averaged \$76,937 overall, or 33% more than chemists.

Comparison of salaries at the job levels BLS considers most equivalent finds attorneys consistently paid more than chemists by amounts

that vary from 4 to 14%. The overall difference in average salary is greater than these level-by-level comparisons would suggest because the highest job level for attorneys is one higher than for chemists. Thus, the highest paid attorneys earn, on average, 40% more than the highest paid chemists do.

BLS's 1989 survey of service-producing industries found too few chemists to measure in four of the seven job levels, since chemists working in industry by and large do so in the goods-producing sector. Chemists at two of the three levels measured earned more than attorneys at the comparable level, about 5% more in each case. Last year, salaries for chemists and attorneys were the same at the third level.

Anecdotal evidence suggests that lawyers' incomes vary enormously, probably much more than those of chemists or people in most other professions. According to an annual survey conducted by *American Lawyer* magazine, partners in the largest law firms in the U.S. often earn over \$1 million per year. In 1989, for example, the 197 partners in the New

## Salary Comparisons

York-based firm of Skadden, Arps, Slate, Maegher & Flom averaged \$1,195,000 in income. Even the starting salaries at New York law firms dwarf the salaries of typical chemists—these averaged \$71,361 in 1988, according to the National Association for Law Placement. Ph.D. chemists working in industry needed 30 years' experience for their 1988 average salaries to be that high. But the attorney general of the state of Montana doesn't make that much, either (\$47,166 in February 1990, according to the *National Law Journal*; the attorney general of Arkansas makes \$26,500), nor does the highest paid lawyer in many public interest organizations (\$66,000 at the American Civil Liberties Union and \$70,000 at People for the American Way, according to the same *National Law Journal* survey).

U.S. attorneys make \$81,400 in 1990, their assistants make from \$24,700 to \$78,200. Such salaries begin to seem more like the kind of income chemists can expect to make. All attorneys working for the federal government in civilian, full-time employment in September 1989 had an average income of \$54,049, according to the federal Office of Personnel Management. Ph.D. chemists working for all government (state and local as well as federal) averaged \$54,200 that same year, according to the ACS survey.

A third profession often held to pay better than chemistry is engineering. According to a 1987 survey by the National Science Foundation, engineers in all fields with Ph.D.s had a median salary of \$50,000, 15% more than the \$50,500 median for chemistry Ph.D.s found in the same survey. Chemical engineering Ph.D.s had a median annual salary of \$60,900, 5% more than engineers as a whole and 21% more than Ph.D. chemists.

More recent data from the Engineering Manpower Commission finds the 1990 median annual salary of engineers working in industry to be \$63,650. According to the ACS survey, chemistry Ph.D.s working in industry in 1990 had median salaries of \$60,000, or 7% less. At the master's level the median salary for chemists in industry is \$47,200, 13% less than engineers with a master's

degree. And at the bachelor's level, chemists in industry earn a median salary of \$40,000, 11% less than engineers with a bachelor's degree. Although these data suggest the same general relationship between salaries in the two professions as the NSF survey does, they give a less reliable comparison between the two fields, because they come from two different surveys.

If the typical engineer earns somewhat more than a typical chemist with the same amount of education, university professors in fields like the humanities usually earn less than their counterparts in chemistry or engineering. According to a report from the American Association of University Professors, full professors in the physical sciences (which include chemistry) at state universities earned an average of \$59,122 for the 1989-90 academic year. That's 17% more than full professors of education in the same schools, 12% more than foreign-language professors, and 11% more than professors of letters, but within 2% of the \$57,997 average salary for full professors in all major fields at these schools. Full professors of engineering earned \$66,342, or 10% more than physical science professors. Only law, computer information, and business professors received higher salaries than engineering professors in this survey, with average salaries of \$78,875 for law (33% more than physical science professors), \$67,026 for computer information professors (33% above physical scientists), and \$66,492 for business (12% more than physical sciences professors).

These field differences are also found among starting salaries for tenure-track positions at these schools. New assistant professors in physical sciences averaged \$34,003 in this survey, very similar to the \$34,164 average for all major fields. Engineering assistant professors start at \$41,845, or 23% more than their physical sciences colleagues. New assistant professors in business had the highest salaries, on average 41% more than physical scientists. In education, they earned 16% less than their physical sciences colleagues, in foreign languages 27% less, and in letters 19% less.

In its 1987 survey, the National Science Foundation found that the \$50,500 median annual salary of Ph.D. chemists was 6% more than the \$47,800 median for all Ph.D. scientists. Only physicists and astronomers (considered a single group with a median of \$53,400), computer specialists (\$54,400), and economists (\$50,800) earned more, among the 15 science fields surveyed. The poorest paid fields were sociology and anthropology, which, with a median salary of \$41,700 was 21% below the median for chemists, and psychologists and agricultural scientists, each with median salaries of \$44,300, 14% less than chemists.

A 1989 salary survey of members of the American Institute of Physics found the median annual salary for Ph.D. physicists employed in industry to be \$63,500, or 9% more than the median for Ph.D. chemists working in industry as measured by the ACS survey of the same year. The median starting salary for new doctoral physicists in 1989 was \$42,480, according to a separate AIP survey of starting salaries. ACS's starting salary survey for Ph.D. chemists that year indicated their median salary was a very comparable \$42,000. Similar to the situation with chemists, new doctoral physicists were paid the most in industry, where the median salary was \$48,720. For chemists, the median salary for new Ph.D.s going into industry that year was \$42,950, or 13% less than physicists.

The American Psychological Association's 1989 survey of its members found the largest single category of Ph.D.-holding psychologists to be those who provide direct human services. The median annual salary of this group was \$55,000.

A 1988 survey conducted by the American Institute of Architects found the median annual salary of architects in firms to be \$39,000. Starting licensed architects had a median salary that year of \$28,000. Such architects rarely have Ph.D.s, according to AIA. Instead, a typical professional education includes five or six years of post-high school study at a university followed by a three-year internship in an architectural firm. Passing a licensing examination is also required. □



## Demand

**An economic downturn, decline in chemical earnings, and the Middle East crisis may lead to a wait-and-see attitude among employers**

Predicting in the autumn what demand for chemists and chemical engineers will be over the coming academic year is always a challenge. This year it's even more so. Following a year when demand was strong for chemists and even stronger for chemical engineers, the fall recruiting season finds the U.S. economy in a downturn, perhaps at the start of a recession. Earnings for chemical companies as a group have declined for each of the past four quarters. And overshadowing everything else is the possibility of armed conflict involving the U.S. in the Middle East.

The employment outlook "starts out with a big 'if,'" says one chemical company recruiter candidly, "and that 'if' is spelled I-r-a-q."

Open hostilities in the Middle East will hurt chemical employment, most observers predict, although even that prediction is qualified. Short-term higher profits for oil companies might be used to expand R&D, and if oil prices could be expected to stay high, it would stimulate alternative fuels development and create jobs for both chemists and chemical engineers. Some chemical company recruiters are waiting to see if the oil companies will be making more and higher-priced offers, especially to chemical engineers, who are already in high demand. For the most part, though, they fear fighting in the Middle East, if it occurs, will jeopardize supplies of petrochemical feedstocks

and further damage chemical companies' profitabilities.

In times of uncertainty, cautious employers "hide and watch," as Rebecca J. Simon, placement director at the University of Illinois' school of chemical sciences, calls it. They may recruit aggressively, but they wait to make firm offers. That's the kind of recruiting year this may be shaping up to be, she says. It will be a very busy recruiting fall at Illinois, with the number of recruiters scheduling visits about the same as last year, "but we'll see how many offers come in in March or April."

She recalls the last downturn in chemical employment, which occurred in 1982 and 1983. The 1981-82 academic year also began with strong company recruiting in the fall, but when the year was over, offers for bachelor's-level chemical engineers nationwide had fallen from 7500 the year before to about 4000. A year later, they were down to about 1150, according to data collected by the College Placement Council.

"It's a confusing time," agrees Joan E. Wheeland, coordinator of the American Chemical Society's employment and career services, which operates the ACS National

Employment Clearing House. Over 200 organizations conducted 2900 interviews during the ACS national meeting in August in Washington, D.C., making it one of the busiest clearinghouses ever. "From the number of interviews taking place, there are certainly jobs out there," Wheel-

land says. Still, she senses from recruiters and applicants alike an uneasiness that the strong demand for chemists and chemical engineers that has characterized the past several years may not continue much longer.

"I see companies hedging," says James D. Burke, manager of professional recruiting for Rohm & Haas research. He expects companies to cut back a bit in their hiring for both bachelor's and advanced degree applicants and in both chemistry and chemical engineering. As recently as the August ACS meeting, recruiters from many of these companies were saying they planned to increase their hiring somewhat at the Ph.D. level in 1991.

Rohm & Haas' current recruiting plans are "about a carbon copy of last year's," in both fields and at all degree levels. These plans, like those of most firms, will be reevaluated in the winter in light of the company's year-end performance. "I don't see our goals increasing from last year," Burke says, "but we sure do plan to hire." As he sees it, the U.S. economy may be easing into a recession, but Europe's isn't, nor are the economies in Japan and the

other high-technology countries of the Pacific Basin. Thus, chemical exports are likely to remain high. Though earnings are down for many chemical firms, sales continue to set record highs, making the long-term outlook hopeful, barring the unknown effects of conflict in the Middle East.

Monsanto, too, plans to hire both chemists and chemical engineers at about the same level as last year, says Robert J. Mason, corporate director of university relations. Altogether, the company's five operating units and corporate research will hire some 65 chemists and chemical engineers at all degree levels. There will be fewer openings in the company's agricultural chemicals area, which is being reorganized, but a corresponding increase in jobs to be filled in the chemicals area, particularly for chemical engineers. The modest increase expected there will be for training people to replace older workers who will be retiring in the next few years, explains Joe Wiley, manager of professional employment for Monsanto Chemical Co. That increase may be trimmed back if the economic outlook worsens, he adds.

Du Pont already has slightly trimmed its hiring plans for both chemists and chemical engineers. "When business goes down, we tend to be more cautious about hiring," says Robert K. Armstrong, manager of professional staffing,

and this seems to be such a time. Overall, the company plans to reduce hiring of both chemical engineers, which it hires primarily at the bachelor's level, and chemists, where by far the most jobs are for Ph.D.s, by 10 to 15%. Chemical engineers have been in such tight supply in recent years that Armstrong expects they will continue in high demand this year, despite the current level of caution among employers. "Ph.D. chemists are not in bad shape either," he says. "In both cases, good candidates will be sought after."

If chemical company profits don't soften further, recruitment by Union Carbide this year will probably be about the same as last year, says Thomas J. Neelen, manager of professional placement for that company. For Ph.D. chemists, that means a continuation of two years of relatively strong demand, where "the supply/demand curve was in favor of the candidate." Last year was a rather typical year for chemical engineering recruitment for Neelen's company. The 1988-89 year was one of its biggest recruiting years for chemical engineers, particularly at the bachelor's and master's level, and last year began with the same level of aggressive recruitment. By December, however, weakness in commodity chemicals markets, in particular, caused the company to cut back its spring recruiting efforts.

Although current plans are for strong hiring this year, a similar revision could occur at several companies this winter. One possible scenario if the economy should worsen, Neelen suggests, is for companies to decide in December that they have already talked to enough applicants on campus for the positions they will have available. "I have some very considerable concerns about a worldwide economic downturn ... or a negative development in the Middle East," he says. "My advice to college seniors would be to get campus interviews in as early as possible, and not rely on companies coming back in the spring."

Similar advice comes from Joseph Schewe, manager of professional employment for PPG Industries. Students should "be a bit aggressive in the fall" and get a firm job offer if they can, he says. Demand for both chemists and chemical engineers looks fairly healthy so far, though he admits to having his fingers crossed about how long it will continue. PPG plans to hire more chemists and chemical engineers this year than last at the bachelor's level, where most of the firm's hiring occurs. Unlike some other chemical employers, PPG's sales and earnings for the first two quarters of 1990 were the strongest in its history and these are fueling its recruitment efforts.

If developments in the Middle East don't change its plans, Phillips Petroleum will be hiring about the same number of chemical engineers this year as the past year as well as "a handful" of chemists, says director of employment and placement William F. Dausses. The company, like many oil companies, has been aggressively recruiting chemical engineers for several years to help build new refineries and redesign older ones to meet new liquid emissions regulations. Pollution concerns also are requiring the reformulation of gasoline, which requires changes at the refinery.

Phillips has no plans at this time to expand its R&D effort, which is where most of the company's Ph.D. chemists and chemical engineers work. Current high oil prices, brought on as they have been by the prospect of military action in the

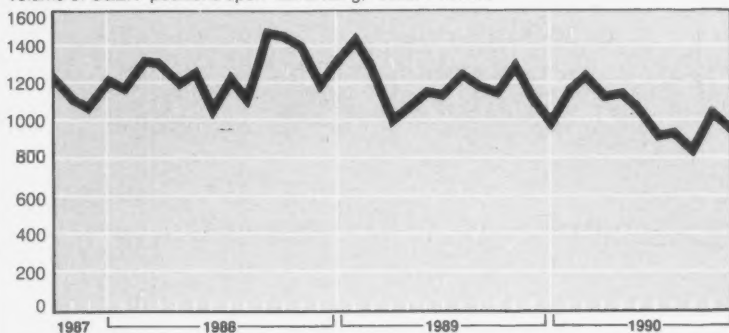
### More Ph.D.s in chemistry and chemical engineering, but bachelor's degrees in both fields are declining

| Academic year | Degrees awarded in chemistry |          |       | Degrees awarded in chemical engineering |          |       |
|---------------|------------------------------|----------|-------|-----------------------------------------|----------|-------|
|               | Bachelor's                   | Master's | Ph.D. | Bachelor's                              | Master's | Ph.D. |
| 1978          | 11,474                       | 1892     | 1525  | 4615                                    | 1237     | 259   |
| 1979          | 11,643                       | 1765     | 1518  | 5655                                    | 1149     | 304   |
| 1980          | 11,446                       | 1733     | 1551  | 6383                                    | 1271     | 284   |
| 1981          | 11,347                       | 1654     | 1622  | 6527                                    | 1267     | 300   |
| 1982          | 11,062                       | 1751     | 1722  | 6740                                    | 1285     | 311   |
| 1983          | 10,746                       | 1604     | 1746  | 7145                                    | 1304     | 319   |
| 1984          | 10,704                       | 1667     | 1744  | 7475                                    | 1514     | 330   |
| 1985          | 10,482                       | 1719     | 1789  | 7146                                    | 1544     | 418   |
| 1986          | 10,116                       | 1754     | 1908  | 5877                                    | 1361     | 446   |
| 1987          | 9,661                        | 1738     | 1976  | 4983                                    | 1184     | 497   |
| 1988          | 9,025                        | 1694     | 1990  | 3926                                    | 1103     | 579   |

Source: National Center for Education Statistics

## Help-wanted ads have been declining since early 1988

Volume of C&EN "positions open" advertising,<sup>a</sup> column-inches



<sup>a</sup> Column-inches published during consecutive periods of four weeks each; no issues were published in last week of 1987, 1988, and 1989.

Middle East, don't necessarily mean increased profits in the long run for oil companies, in the company's view. "That could go either way," Dausses says. "The higher oil prices go now, the lower they'll go when the hostilities are over—whether that's in two months or 10—because there will be more production." But if disruptions in supply lead to an economic recession, demand for chemists and chemical engineers will go down.

If it can find them, Exxon hopes to hire as many as 25% more chemical engineers this year, says Susan Ottsen, technical recruiting coordinator for Exxon Co., USA. With fewer students expected to graduate this year than last with chemical engineering degrees, she predicts demand will stay high. Exxon was unable to hire as many chemical engineers as it wanted last year, which partly accounts for the company's higher recruiting targets this year. Demand for chemists, who Exxon hires primarily at the Ph.D. level for R&D positions, will be about the same as last year, she says.

Nalco Chemical, like a number of other specialty chemical producers, has seen its earnings rise during the past year. But that's not translating into more jobs for chemists. The company had a major expansion of its R&D staff last year and won't be hiring quite so aggressively this year, though it still expects some 20 to 30 openings for Ph.D. chemists during the year, according to Karen

Nordquist, manager of technical employment. Last year, the company sought roughly twice that many. "We were able to fill all the expansion positions," Nordquist says, "and we saw good applicants."

Although earnings at Merck—and pharmaceutical companies generally—have held up much better than for chemical producers during the past year, that company will be cutting back a bit in its plans for hiring chemists this year. Last year the company hired 75 to 100 chemists. "We're trying to stem our growth in R&D staff, which has been occurring at about 10% per year," explains Teresa Merinelli, manager of college relations for Merck. This year, Merck aims to expand the R&D staff 7.5%. It also plans to hire some 50 to 75 engineers—mostly chemical engineers—which is slightly fewer than last year.

Upjohn will be hiring some chemists this year, perhaps 12, up a bit from last year, but not at the levels of 30 to 40 per year that the company had in 1986 to 1988, according to recruiting representative Marinus Dejong. In addition to staff replacements, the positions include some expansion in Upjohn's fine chemicals division, in anticipation of expanding markets in this area in Eastern Europe.

Despite expressions of concern about how long it might last, the picture in university placement offices this fall is definitely one of heavy recruitment for both chemists

and chemical engineers. At the University of Wisconsin, for example, the number of companies that signed up to recruit Ph.D. chemists this year is the same as last, which was a very good recruiting year, according to chemistry department placement coordinator, Audrey L. Aylesworth.

More organizations have scheduled interviews this year at the University of California, Berkeley's career planning and placement center, says Linda Lewis, technical career adviser for chemistry and chemical engineering there. This center handles the bulk of bachelor's level interviews at the university. Demand is up particularly for chemical engineers. "We've not seen a lot of cancellations," Lewis says. If anything, demand is picking up for chemical engineers at Wisconsin, says Sandra Arnn, director of career planning and placement at the college of engineering. Traditional chemical companies, as well as pharmaceutical, petroleum, and environmental firms all seem to have growing needs for chemical engineers at a time when enrollments are declining. The result is a student's market, in which many graduates had three or four job offers last year and the average salary offered rose 15% from the year before. As many as 25% of last year's graduates also received supplemental payments "in the \$1000 to \$2000 range" to encourage them to go to work for particular employers, Arnn says.

Chemical engineering graduates at the University of California, Los Angeles, averaged six offers per student last year, according to Manuel Perez, director of engineering and science placement there. This demand is definitely continuing, he says, fueled—particularly in California—by the expanding market for environmental firms. Traditional engineering companies also are expanding their chemical engineering recruitment, as their business shifts increasingly to constructing plants that meet tighter pollution controls. The demand is even spilling over to bachelor's level chemists, he says, who are being hired in some cases to fill chemical engineering positions where engineering graduates can't be found. □